SURGE EFFECTS FROM HURRICANE ELOISE

BY

Walter W. Burdin

Navigation and Coastal Branch, Planning Division
U. S. Army Engineer District, Mobile
Mobile, Alabama

INTRODUCTION

Hurricane Eloise was the first major storm to directly impact the Panama City beaches since that area started to develop after World War II. (The Panama City beaches is defined as the 18.5 mile reach between Philips Inlet and the Panama City Harbor Entrance.) Because of the recent rapid growth of tourist-oriented facilities, Eloise was the most destructive storm ever experienced there.

HISTORY AND CHARACTERISTICS OF THE STORM

According to its Meteorological History (1), Hurricane Eloise was spawned by a disturbance that left the African Coast on September 6, 1975. Bulletins began reporting it as a tropical depression east of the Virgin Islands on September 13th. As a tropical storm, it brought torrential rains to the Virgin Islands and Puerto Rico and caused severe damage from flooding.

Eloise strengthened rapidly and had reached minimal hurricane force prior to striking the northeast coast of the Dominican Republic late on the 16th. The center tracked westward across southeastern Cuba into the Caribbean north of Jamaica. (Figure 1) This passage over land caused it to deteriorate to tropical storm status again.

Eloise remained poorly organized until it approached the Yucatan Peninsula on the 20th. On September 21st the storm emerged from Yucatan to encounter favorable conditions for intensification in the Gulf of Mexico. It headed north, regaining hurricane status about 350 miles south of New Orleans on the morning of the 22nd. As the day passed Eloise turned to the NNE, increased its forward speed, and continued to intensify.

Early on the morning of September 23rd, shortly after 7:00 AM CDT, the storm moved inland over the gulf coast of Florida, with the center of the eye crossing Dune Allen, a small community about half-way between Pensacola and Panama City. At that time it was still moving NNE at about 23 knots, the eye was 20 miles in diameter and maximum sustained surface wind was estimated to be 110 knots. The highest sustained winds along the coast were not measured as most measuring equipment failed. However, a gust to 135 knots was observed on a tower near Panama City. Hurricane force winds were reported from Fort Walton Beach to Panama City and northward into extreme southeastern Alabama.

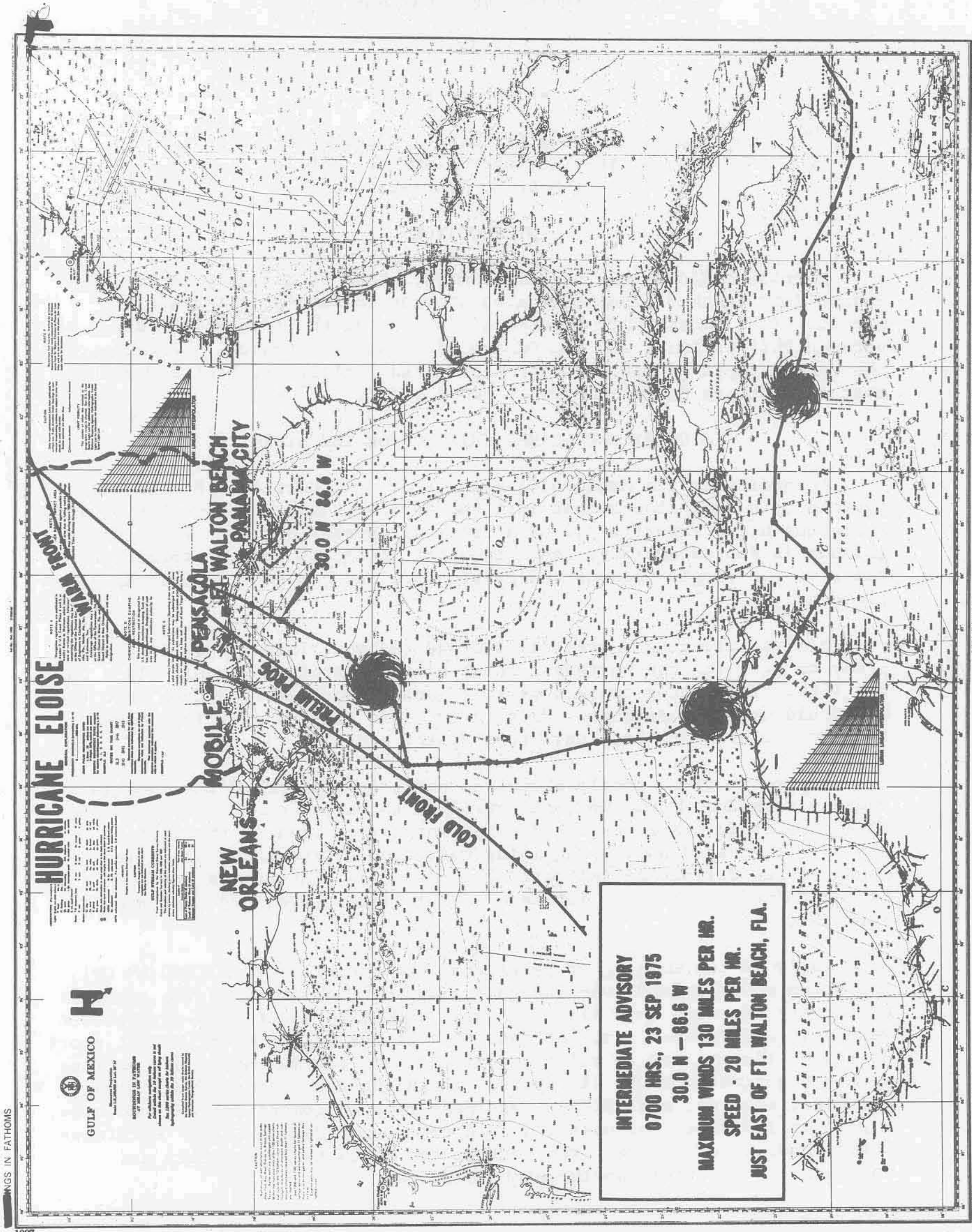


Figure 1 - Map of Storm Track for Hurricane Eloise

Figures 2 and 3 are aerial photographs taken by a press photographer from a U. S. Coast Guard aircraft which flew a reconnaissance over the area shortly after the eye passed inland. The photographs were taken at about 10:00 AM. Note that there is apparently no rain. Fortunately for the coastal region, there was relatively light rain during landfall.

Figure 2 - Aerial Photo taken during Storm - just East of Philips Inlet

The storm inflicted heavy damage along the coastline, especially to the highly developed area of the Panama City beaches. As Eloise moved rapidly inland, it caused heavy rainfall in eastern Alabama and Tennessee. By September 24th it had passed through Virginia into Pennsylvania and was triggering flash floods in the upper Ohio Valley and Mid-Atlantic States. Interaction with a coldfront produced a storm which continued into the northeast.

Summarizing the characteristics of Hurricane Eloise at landfall:

Observed minimum pressure	-	955 mbar	(28.20 inHg)
Maximum sustained winds	-	110 knots	(127 m.p.h.)
Forward speed	-	23 knots	(26.5 m.p.h.)
Eye diameter	-	20 naut. mi.	(23 mi.)
Radius of maximum winds	-	20 naut. mi.	(23 mi.)

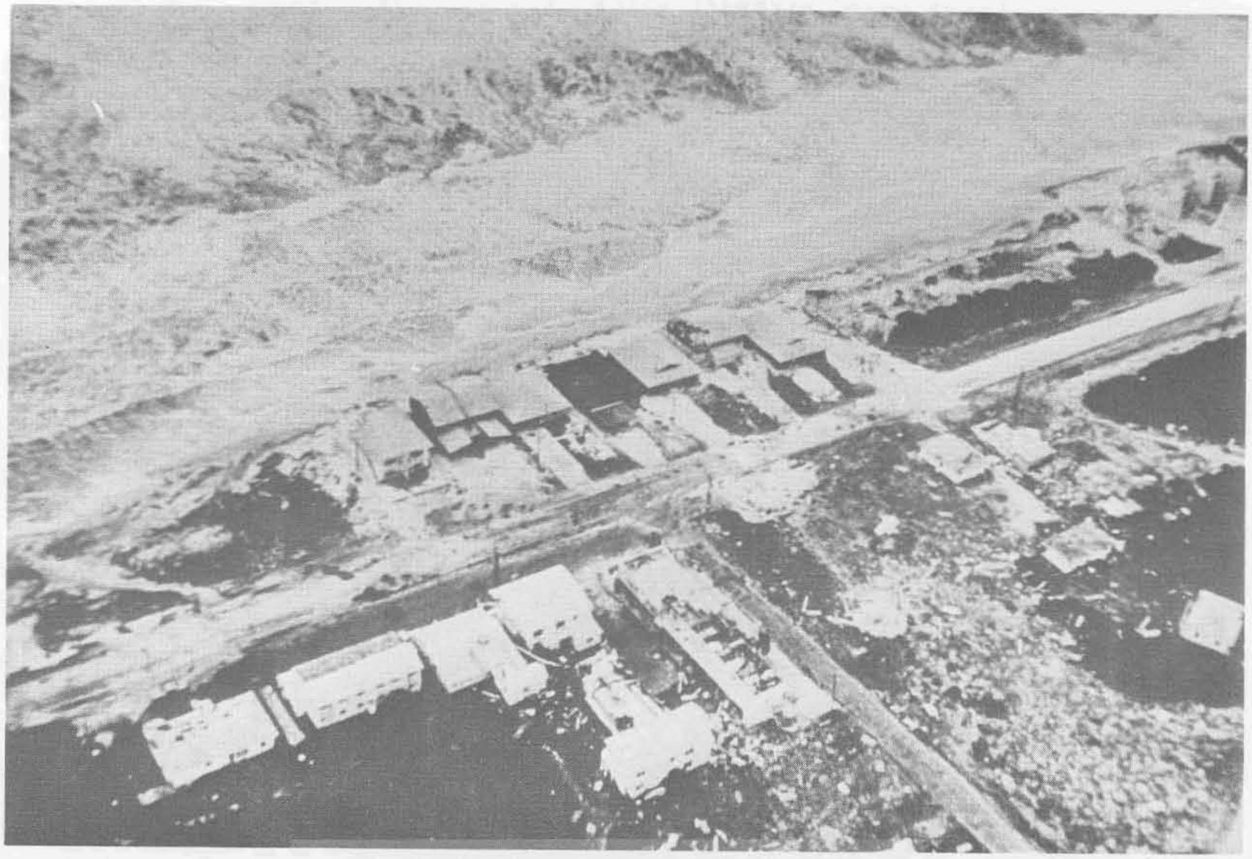


Figure 3 - Aerial Photo taken during storm - Further East than Fig. 2

The National Weather Service (NWS) has a simplified scale for classifying hurricanes. (Figure 4) Any storm of Category 3 or greater is considered a major storm. Hurricane Eloise was a Category 3 storm on this scale. The Weather Service forecast a 10-foot high open coast surge for Eloise. By way of comparison, Hurricane Camille, a Category 5 storm, had a maximum storm surge of 22.6 feet, mean sea level (m.s.l.).

HURRICANE ELOISE STORM SURGE

Figure 5 shows the various components that combine to produce the change in water level called a hurricane, or storm, surge, also frequently referred to as hurricane, or storm, tide. The figure was taken from the Shore Protection Manual (SPM) prepared by the U. S. Army Coastal Engineering Research Center (2). Methods of computing these components are discussed in some detail in the SPM and so will not be repeated here.

The computational technique, as developed in the Galveston District about 13 years ago, is a fairly simple one which can be carried out on a desk calculator, although it is more commonly done on a computer now. It predicts the peak surge where the radius of maximum winds intersects the shoreline (the "open coast surge"). The computation does not include S_w, the breaking wave setup, which will be discussed further below, nor does it include the actual waves which ride atop the surge.

DEFINITION OF THE SAFFIR/SIMPSON SCALE

CATEGORY	WINDS (mph)	SURGE (ft)	EXAMPLES: FLORIDA COAST
1	74-95	4-5	AGNES 1972
2	96-110	6-8	CLEO 1964
3	111-130	9-12	BETSY 1965
4	131-155	13-18	DONNA 1960
5	GREATER THAN 155	GREATER THAN 18	1935 STORM

Figure 4 - Hurricane Classification Scale used by National Weather Service.

Using the NWS storm parameters discussed earlier, the results from the computer were:

S_x - x - Component Setup - 6.54 feet

S_y - y - Component Setup - 1.87 feet

$S_{\Delta P}$ - Atmospheric Setup - 1.19 feet

S_A - Astronomical Tide - 1.34 feet

S_e - Initial Water Level - 1.00 feet

This data is referred to mean low water in the computation and can be converted to mean sea level (m.s.l.) elevations by subtracting 0.29 feet.

S_e, the initial water level, is usually taken as 1 foot since experience indicates that the presence of a hurricane in the Gulf of Mexico will usually cause a general rise in water levels of that amount.

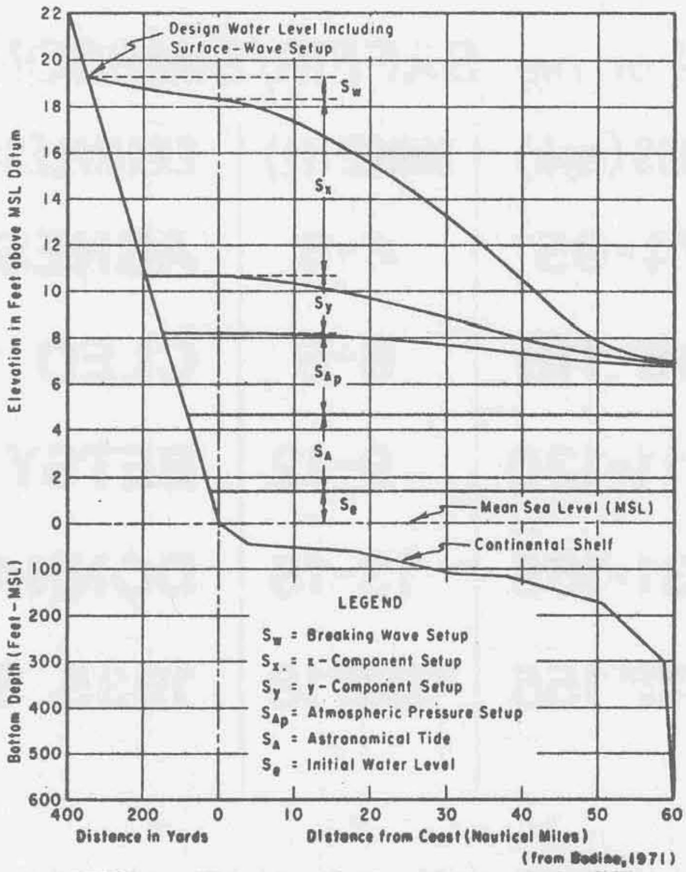


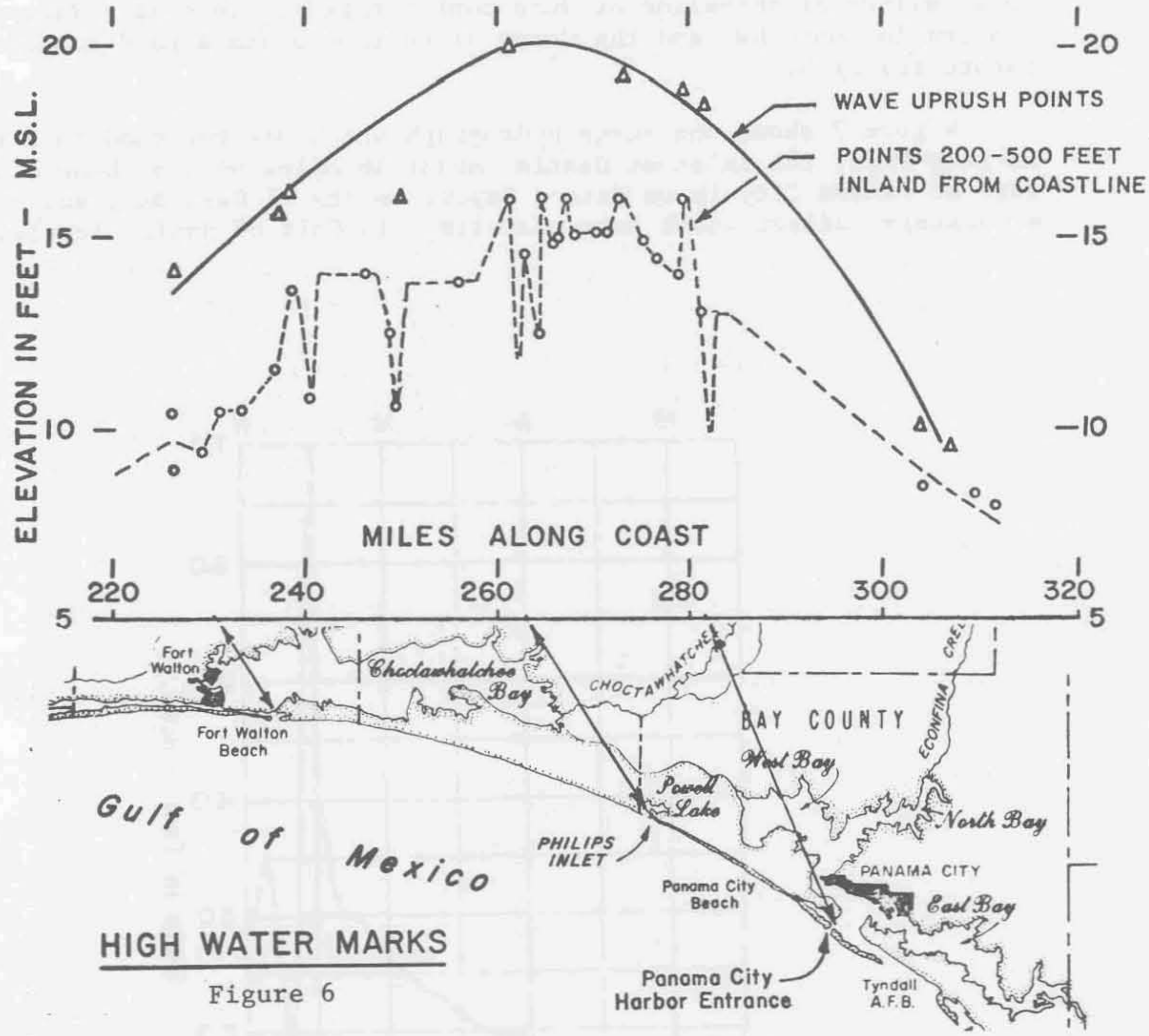
Figure 5 - Hurricane Surge Components

According to the Tide Tables (3) prepared by National Ocean Survey, high tide for the Panama City region occurred at 10:49 PM on the night of September 22nd and low tide would have been 8:53 AM on the morning of the 23rd. Since the hurricane crossed the coast on a falling tide at about the time the minimum stage would have been reached, the S_A component can be neglected.

Summing up the appropriate components and correcting to mean sea level yields a peak open coast surge elevation of 10.3 feet m.s.l.

NWS has a more sophisticated two-dimensional method for computing surge heights, the SPLASH model, developed in recent years by Jelesnianski and others. NWS forecast a 10-foot open coast surge at landfall and their after-the-fact calculations yielded a surge of 10.5 feet m.s.l.

Almost immediately after the storm, Mobile District crews began surveying the high water marks left by Eloise. Figure 6 shows the results of their efforts. You will note that the actual, on-shore, high water elevation ranged between 15 and 16 feet m.s.l. throughout the Panama City beaches where the worst damage occurred. Although the use of high water marks for determining surge height is not a completely reliable method, it is obvious that there is a major discrepancy between the computed open coast surge and the high water actually experienced.



HIGH WATER MARKS

Figure 6

Can this discrepancy be accounted for by the neglected S_w component? The formula from the SPM for this factor is:

$$S_w = 0.19 \left[1 - 2.82 \left(\frac{H_b}{gT^2} \right)^{\frac{1}{2}} \right] H_b$$

where H_b = Wave height at breaking, ft

T = Wave period, seconds.

If it is assumed that the wave is breaking over the zero m.s.l. contour then the breaking depth is 10.3 feet. From wave theory

$$d_b = 1.28 \ H_b$$

So H_b = 8 feet. Obviously, with a very long wave period (<u>not</u> typical of hurricanes) the term in the brackets approaches one and the maximum $S_w = 0.19 \ H_b$ or 1.52 feet. Assuming periods typical of hurricane waves (say T = 4 to 10 seconds) yields a value in the range of 1.2 feet for S_w.

Apparently, the major discrepancy lies elsewhere, possibly in some local effect of shoreline or dune configuration. This is a matter of some concern for both NWS and the Corps of Engineers and a good subject for future research.

Figure 7 shows the surge hydrograph which was recorded on a tide gage at East Pass, the inlet at Destin, about 16 miles west of Dune Allen. (The gage at Panama City is on Watson Bayou, an arm of East Bay, and does not accurately reflect short term variations in Gulf of Mexico levels.) The

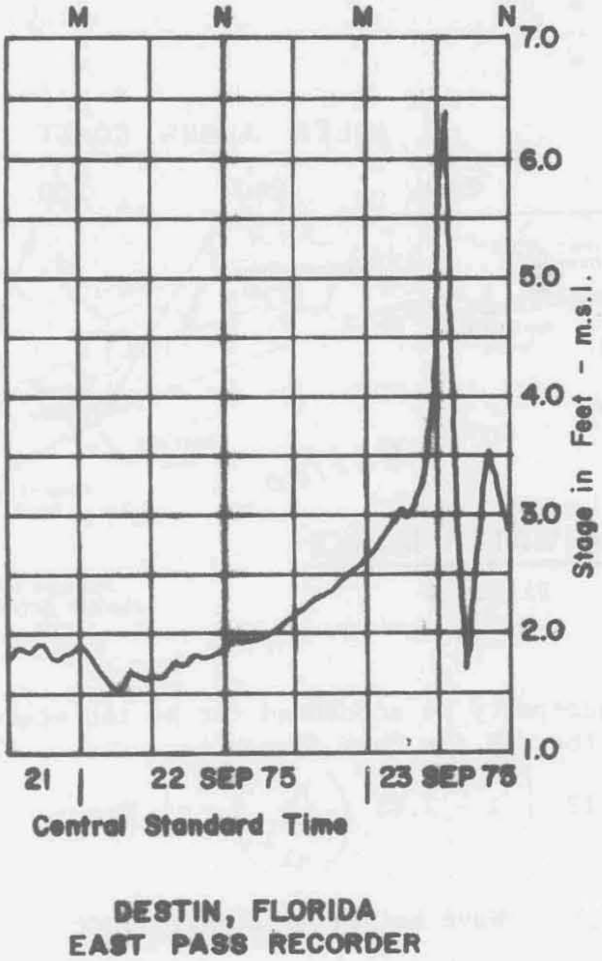


Figure 7

shape of the hydrograph is similar to that of other major hurricanes. Water level rises slowly as the storm approaches and then quite rapidly as the eye crosses the coast. The effect is that of a sharp spike from 3.0 feet to 6.4 feet and with a base width of 2½ hours at the 3-foot stage. The secondary spike was probably caused by outflow from Choctawhatchee Bay as the winds reversed.

STORM DAMAGE TO THE PANAMA CITY BEACHES

Figure 8 is an aerial photograph taken in June 1975 which shows development typical of the area. Destruction along the beach was extensive and in proportions never witnessed before in northwest Florida. Figures 9 through 14 show typical damages from Hurricane Eloise. The majority of the development along the beaches is atop or in front of the primary dune.

Figure 8 - Typical Development of Panama City Beaches - June 1975

Figure 9 - Storm Damage to the Rountowner Motel

Figure 10 - Another View of the Rountowner

Figure 11 - Typical Damage from Hurricane Eloise

Figure 12 - Typical Damage from Hurricane Eloise

Figure 13 - Typical Damage from Hurricane Eloise

Figure 14 - Typical Damage from Hurricane Eloise

Protection from high tidal effects and/or storm surges is not provided except by bulkheads. Generally damages were relative to the proximity of the structure to the water's edge where the buildings closest to the water suffered the most extensive damages. Many of the bulkheads were reduced to rubble. Patios, pools, recreational equipment, structures, fill material and parking lots behind bulkheads were lost or severely damaged. The first floor of most motels and condominiums on the beach were gutted of furniture and fixtures. Load bearing walls remained intact but wall panels and glass were destroyed by the surge and wave action. Estimates of the total damages vary, but are on the order of $80 million for the 18.5 mile reach.

Again using Hurricane Camille as a benchmark, structures on the Florida Coast were severely damaged, but few were totally demolished, while on the Mississippi Coast structures within the water's reach were, in most cases, simply gone, leaving only stripped foundations. This illustrates the difference in the severity of the two storms. There were also differences in terrain. Despite poor building practices in recent years, the Panama City beaches still had a good dune line. Although severely eroded the dunes were overtopped or cut through in only a few locations and the major damage was to structures fronting or topping the dunes. The Mississippi Coast has no dunes and so the full Camille surge carried inland unobstructed.

DISASTER ASSISTANCE OPERATIONS

ER 500-1-1, implementing PL 84-99, provides for certain Corps of Engineers activities in connection with flood and coastal storm emergencies. The primary objectives are to save life or prevent suffering or major damage. Damage surveys immediately after the storm were conducted under this authority.

Disaster relief and assistance under PL 93-288 are provided at the request of the Federal Disaster Assistance Administration (FDAA). Services provided include the damage investigations needed for a Presidential determination as to the need for a "Major Disaster" Declaration; removal of wreckage and debris; emergency repair and temporary replacement of public facilities; protective work essential to the preservation of life and property; and other technical assistance.

After the "Major Disaster" Declaration, the Mobile District advertised and awarded, in October 1975, three debris removal contracts which covered coastal Bay County from about Philips Inlet to St. Andrews State Park. (See Figure 15) There contracts were let for an estimated debris yardage at a specified unit cost and the three ultimately totalled $76,457.00. Figure 16 is a typical "cleanup" scene. Three demolition contracts were awarded in January 1976 in the total amount of $23,135.00 and a fourth in the amount of $14,565.00 was awarded on March 12, 1976. Figure 17 shows a typical demolition job. All work has been completed.

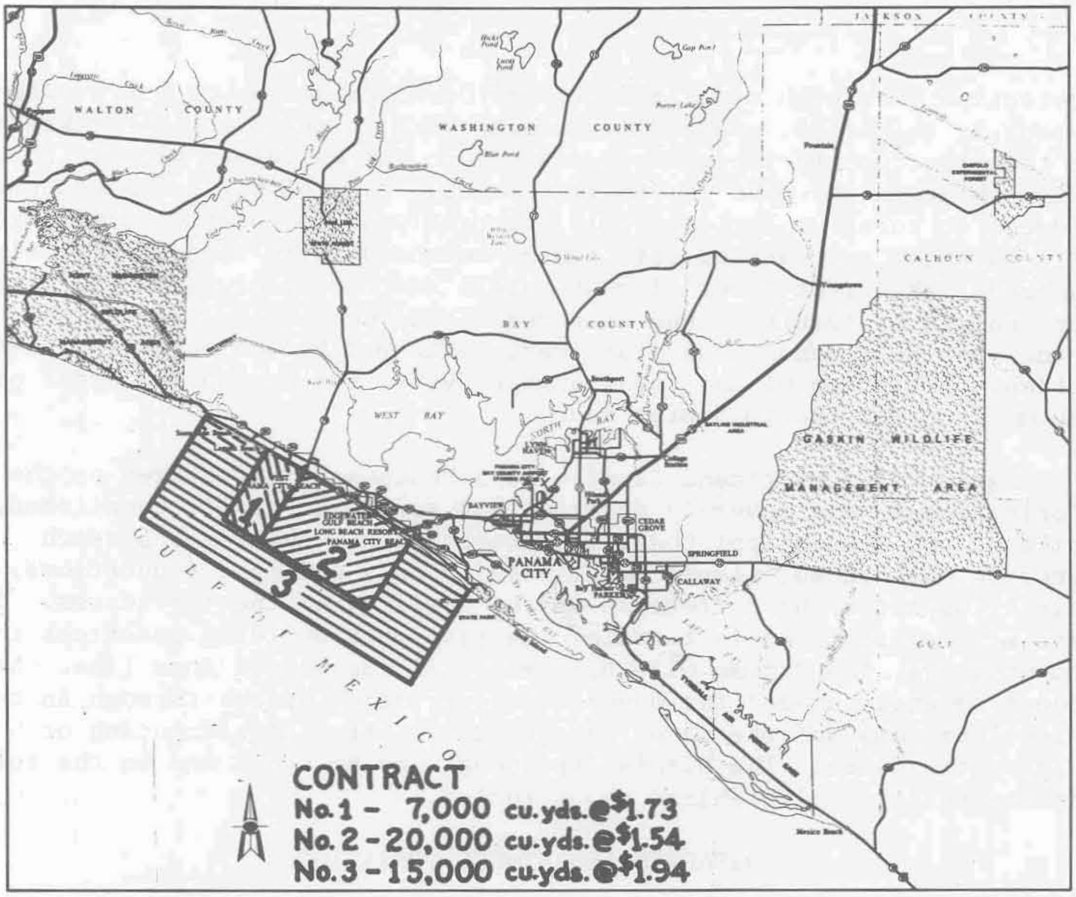


Figure 15 - Map showing Debris Contract Coverage

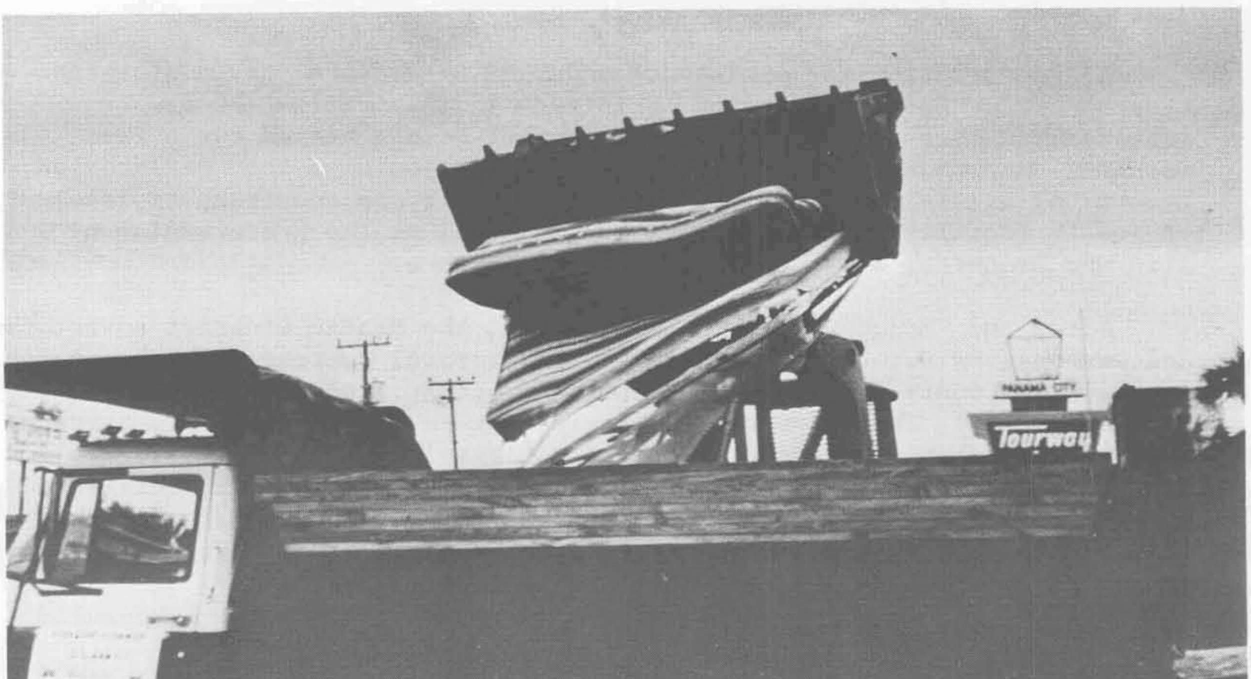
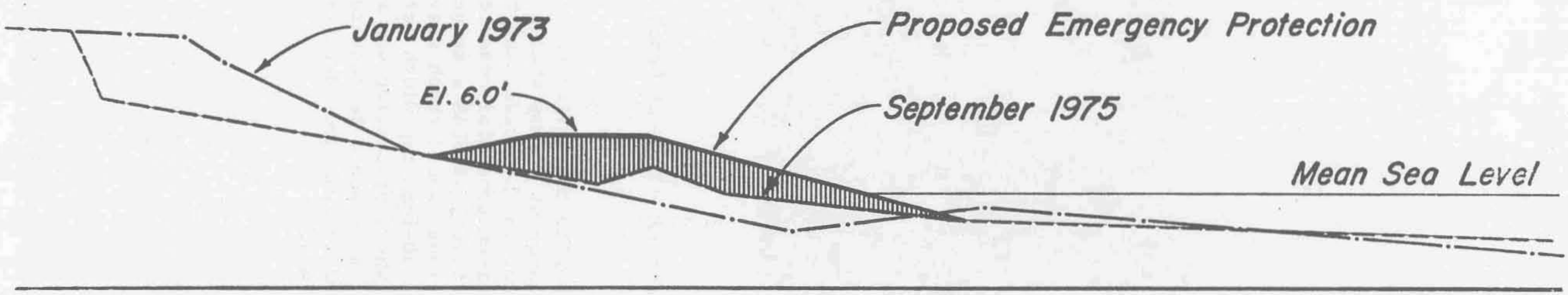


Figure 16 - Typical Debris Removal Scene

Figure 17 - Typical Demolition Scene

The FDAA has authority to provide emergency protection against additional damage from subsequent storms when a major disaster has destroyed the existing protection, in this case, the beach and dunes. This work is limited to "the minimum essential measure" to protect against a 5-year storm. The Mobile District, at FDAA's request, determined that a 5-year storm surge plus wave runup would reach elevation 6, mean sea level. The District recommended a 30-foot top width berm to elevation 6 at 25 locations along the beach where protection was required and estimated that 238,000 cubic yards of sand would be required. (See Figure 18) That work has been requested by FDAA and advertised for construction. Bids will be opened on May 4th.



SECTION SHOWING PROPOSED EMERGENCY PROTECTION

Figure 18

25 0 25
HORIZONTAL SCALE IN FEET

10 0 10
VERTICAL SCALE IN FEET

REFERENCES

1. Hurricane Eloise, September 13-24, 1975, Meteorological History, National Hurricane Center, National Oceanic and Atmospheric Administration (NOAA)/National Weather Service, P. O. Box 248286, Coral Gables, FL 33124.

2. Shore Protection Manual, U. S. Army Coastal Engineering Research Center, Kingman Building, Fort Belvoir, VA 22060.

3. Tide Tables 1975, High and Low Water Predictions, NOAA/National Ocean Survey, Rockville, MD 20852.